

Tool 13

Comparative Subwatershed Analysis (CSA)

This tool contains information on the Comparative Subwatershed Analysis that helps screen subwatersheds within a community to find the ones with the greatest restoration potential. A brief description of the subwatershed “metrics” used to provide a general indication of restoration potential is also included. The information provided within this tool is an excerpt from Schueler and Kitchell, 2005.

D-2	Desktop Analysis Comparative Subwatershed Analysis	CSA
Purpose The CSA screens subwatersheds within a community to find the ones with the greatest restoration potential. The CSA involves a simple spreadsheet analysis of selected subwatershed “metrics” that provide a general indication of their restoration potential. Metrics are derived by analyzing available GIS layers and other subwatershed data sources. Subwatersheds with the highest aggregate score become priorities of subsequent field investigations for actual restoration potential.		
Scale Community- or Watershed-wide		Value Helpful
Analysis Method Four tasks are involved in conducting a Comparative Subwatershed Analysis: <ol style="list-style-type: none">1. Delineate subwatersheds and review available metric data2. Choose and compute metrics that best describe restoration potential3. Develop weighting and scoring rules to assign points to each metric4. Compute aggregate scores and develop initial subwatershed ranking		
Mapping Needs The CSA requires an extensive analysis of existing mapping layers and other data, as shown in Table 8. The basic trick is to develop a subwatershed-specific attribute table for each layer, and then compute a single numeric subwatershed metric for that indicator.		
Other Data Needs Summary subwatershed metrics can also be derived from the existing data analysis (EDA) and from stakeholder input (see Table 9).		
Product The priority list is supported by a short report that documents how the metrics were derived, scored and weighted. A watershed map that shows the locations of priority subwatersheds is also produced.		
Time Frame / Level of Effort A CSA can normally be completed in three or four weeks of staff time, if GIS data layers are available.		
Where Cited Appendix D of this manual provides extensive guidance on preparing a CSA.		
Tips for Conducting a Comparative Subwatershed Analysis <ul style="list-style-type: none">• The quality of the CSA often depends on good subwatershed delineations. While delineation is more of an art than a science, it is a good idea to try to define subwatersheds that are roughly the same size and have a relatively homogenous character.• An excellent slideshow on subwatershed delineation techniques can be accessed online at: http://www.stormwatercenter.net/Slideshows/delineating_boundaries_files/frame.htm.• The CSA is the first real test of your watershed-based GIS, so expect a lot of headaches with data compatibility.		

Appendix D: A Review of Subwatershed Metrics

This appendix describes the range of possible upland and stream corridor metrics that can be employed in a Comparative Subwatershed Analysis (CSA- See Chapter 2). The rationale behind each metric is explained, in terms of how it influences restoration potential and the feasibility of different types of restoration practices. Guidance is offered on the units to measure each metric, and how to derive it from available mapping and other data sources. An overall summary of subwatershed metrics is provided in Table D1.

Review of Upland Metrics

1. Current Impervious Cover (% of subwatershed)

Impervious Cover (IC) is a powerful predictor of stream impairment and overall subwatershed restoration potential (see discussion on Impervious Cover Model in Manual 1, and CWP, 2003). Generally, subwatersheds with lower IC have greater overall restoration potential. Low IC normally indicates a greater range of potential candidate sites for retrofit, stream repair, reforestation and source control practices. IC is not a reliable indicator of the feasibility of discharge prevention practices. Subwatershed IC can be directly derived from GIS land cover layers, or indirectly estimated based on GIS land use layers using standard land use/impervious cover coefficients (See Cappiella and Brown, 2001).

2. Current Forest Cover (% of subwatershed)

Total subwatershed forest cover (FC) has a strong positive influence on stream quality. Generally, subwatersheds with a high percentage of FC possess better stream quality.

From the standpoint of restoration feasibility, however, low levels of subwatershed FC often indicates more potential sites for upland reforestation practices, and indirectly, retrofit, stream repair and riparian reforestation practices, as well. A GIS can depict forest in terms of either forest canopy or forest cover. Forest canopy is a direct measure of the total subwatershed area covered by tree canopy, whereas forest cover is a more indirect measure (sum of the polygons in which trees are the dominant land cover). Consequently, forest canopy is usually greater than forest cover. Forest cover can usually be derived from standard land cover layers, whereas forest canopy may require further analysis of high-resolution aerial photos or satellite imagery. If forest cover is not accurately shown on the GIS, it should be directly estimated from aerial photos. (Cappiella et al., 2005a)

3. Density of Storm Water Ponds (Ponds/square mile)

This metric is a general index of the extent of current storm water treatment and future retrofit potential within a subwatershed. In general, a high pond density indicates strong restoration potential, since there are many potential candidate sites for storage retrofits and upland reforestation practices. Not every community tracks storm water ponds in their GIS, so it may be necessary to check with the local storm water management authority and inspect files to derive subwatershed pond density.

Table D1: Summary of Subwatershed Metrics		
Subwatershed Metric	Indicates higher restoration potential when:	And suggests that the following restoration practices may be feasible:
1. Current Impervious Cover (% IC)	Current impervious cover is low Less than 10% = 10 pts, 11 to 25% = 7 pts, 26 to 40% = 5 pts, 41 to 60% = 3 pts, >60% = 1 pt	Low IC suggests a range of possible sites for all practices, but particularly storage retrofits and stream repairs
2. Subwatershed Forest Cover (% FC)	Forest Cover and IC are both low Less than 10% = 10 pts, 11 to 25% = 7 pts, 26 to 40% = 5 pts, 41 to 60% = 3 pts, >60% = 1 pt	Low FC suggests widespread potential for upland and riparian reforestation
3. Storm Water Pond Density (ponds/mi ²)	Pond density is high Award one point for each pond per square mile	Existing pond sites are good candidates for storage retrofits, reforestation of pond buffers, and downstream repairs
4. Subwatershed Development Potential (% developable)	No more development is expected Deduct one point for each 5% of subwatershed area subject to future development	Stable conditions improve the feasibility of all practices, particularly for stream repairs and storage retrofits
5. Publicly-Owned Land (% of subwatershed)	Public land ownership is high Award one point for each 2.5% of subwatershed in public ownership	Provides a wide range of potential sites for all restoration practices
6. Detached Residential Land (% of subwatershed)	Detached residential land is high Award one point for each 10% of subwatershed in public ownership	Suggests strong feasibility for neighborhood source control, on-site retrofits and upland forestry
7. Age of Subwatershed Development (decades from buildout)	At least three decades have passed since buildout Award maximum points for these older subwatersheds	Stable conditions improve the feasibility of all practices, particularly for stream repairs and storage retrofits
8. Industrial Land (% of subwatershed)	Industrial land is high Award one point for each 2% of subwatershed classified as industrial	Suggests strong potential to implement source control, discharge prevention and on-site retrofits
9. Storm Water Hotspot Density (potential hotspots/mi ²)	Hotspot density is high Award two pts for each hotspot per square mile	Suggests strong potential to implement source control, discharge prevention and on-site retrofits
10. Age of Sewer System (decades)	Aging sewers systems cause water quality problems Add one point for each decade since the sewer system was constructed	Discharge prevention and enhanced municipal operations (e.g., SSO controls)
11. Sum of Forest, Wetlands and Parks (% of subwatershed)	Sum of all three is high Award one point for each 2% of subwatershed area in the three uses	Upland and riparian reforestation, natural area restoration, stream repairs and some storage retrofits
12. Citizen Concern (index)	Citizen concern is high Award points based on stakeholder assessment of subwatershed concern	Suggests strong support for full range of restoration practices

Table D1: Summary of Subwatershed Metrics		
Subwatershed Metric	Indicates higher restoration potential when:	And suggests that the following restoration practices may be feasible:
14. Subwatershed Stream Density (stream miles/mi ²)	Stream density is high Deduct one point for each 5% reduction in stream density from local average	Greater feasibility of all corridor practices: storage retrofits, stream repair, riparian management and discharge prevention
15. Stream Corridor Forest Cover (% forested)	Corridor forest cover is low Deduct one point for each 10% reduction in forest cover	Suggests feasibility of riparian reforestation and wider range of sites for storage retrofit and stream repairs
16. Available Stream Corridor Area (acres /stream mile)	Open corridor acreage is high Add one point for each two acres per stream mile available	Suggests feasibility of riparian reforestation and wider range of sites for storage retrofit and stream repairs
17. Road Crossings (crossings/stream mile)	Headwater crossings are numerous Add point for each one crossing/stream mile	Storage retrofits, stream repairs and culvert modifications, stream adoption. <i>NOTE: Use Metric 20 to assess fish barriers</i>
18. Storm Water Outfall Density (outfalls/stream mile)	Stormwater outfall density is high Add one point for each ten mapped outfalls/stream mile	Potential sites for storage retrofits and probable risk of illicit discharges
19. RBA Composite Scores (varies)	RBA score is higher/lower than predicted by ICM Add points based on input from monitoring experts	Indicates need for all restoration practices, including stream repair
20. Connection to Downstream Waters (open/impeded)	Downstream connection are open Deduct one point for each major crossing/stream mile	Indicates overall feasibility of fishery recovery and potential need for fish barrier removal and stream repair
21. Public Ownership of Corridor (% of corridor)	Public corridor ownership is high Add one point for each 10% of the stream corridor in public ownership	Greater feasibility of all corridor practices: storage retrofits, stream repair, riparian management and discharge prevention
22. Violations of WQ Standards (Violations/yr)	Standards are frequently exceeded Add points based on number of annual violations	Suggests need to focus on pollutant reduction through discharge prevention, source control and retrofits
23. Fishery Status (Varies)	F-IBI score is higher/lower than predicted by ICM Add points based on input from fishery experts	Suggests potential to recover fish community through stream repairs, retrofits and riparian reforestation
24. Corridor Recreational Value (index)	Recreational use or value is high Add points based on stakeholder input or measured uses	Suggests strong support for full range of restoration practices
25. Water Quality Regulatory Status	Subwatershed or receiving water has special mgmt designation Add points based on input from regulatory experts	Suggests regulatory need to focus on pollutant reduction through discharge prevention, source control and retrofits
26. Severity of Flooding Problems (index)	Flooding problems are severe Add points based on flooding measures (see text)	Suggests need to focus on flood reduction via storage retrofits and riparian management
27. Severity of Streambank Erosion (index)	Streambank erosion is severe Add points based on bank erosion scores (see text)	Suggests need to focus on bank stabilization through storage retrofits and stream repairs

4. Subwatershed Development Potential (% of subwatershed)

Many urban subwatersheds are not yet fully built out, so it is important to project the amount of incremental IC that could still be built in the future. In general, subwatersheds that still have considerable development potential have poor prospects for restoration, since new development will generate more storm water impacts that could offset any improvements due to restoration practices. In addition, extensive subwatershed development potential negatively affects the feasibility of storm water retrofit, stream repair and upland forestry practices. Subwatershed development potential is derived through analysis of zoning maps and development forecasts. First, the remaining amount of developable land in the subwatershed is estimated. Next, the corresponding IC associated with the future development is calculated using land use/IC coefficients. Desktop methods to determine subwatershed development potential and predict future changes in subwatershed IC are presented in Capiella *et al* (2005a).

5. Publicly-Owned Land (% of subwatershed)

This metric is important because publicly owned lands are the preferred location for most restoration practices. Subwatersheds with a high percentage of publicly owned land tend to have greater restoration potential because they offer a greater number and range of potential sites to systematically install storage retrofit, stream repair, and upland forestry practices. Public land is operationally defined as the aggregate of local, state, federal and tribal parcels above a minimum threshold size (e.g., 2 acres). Public owned land is relatively easy to derive from GIS land use layers, particularly if tax or parcel data are available to confirm ownership.

6. Detached Residential Land (% of subwatershed)

The proportion of a subwatershed in detached residential land use is a useful metric since neighborhoods can be significant source of pollutants as well as a potential location for on-site retrofits. In general, subwatersheds with a high percentage of residential land have greater restoration potential. Residential land is a strong indicator of the feasibility of on-site retrofit, pollution source control and upland forestry practices. The amount of residential land in a subwatershed is easily computed from GIS land use and zoning layers, or by visible inspection of maps.

7. Age of Subwatershed Development (+ or - decades from buildout)

This metric expresses the age of subwatershed development as the number of decades before or after buildout. Buildout is defined as the point at which major development ceases, and a subwatershed attains its maximum degree of impervious cover (beyond minor redevelopment). The age of development is an important subwatershed metric, since it provides useful clues about the potential for storm water retrofits, illicit discharges, and forest loss. In addition, the age of subwatershed development is a critical feasibility factor for stream repair practices since streams may take several decades to fully adjust to upstream development. In general, older subwatersheds (30 + years) have greater restoration potential than younger ones. In reality, most subwatersheds are a complex mosaic of structures built in many different eras, making it impossible to derive an exact estimate of the average age of development. A rough estimate, however, is all that is usually needed, and this can be inferred from plat or parcel data, or through a simple drive-by survey of the subwatershed (see NSA in Manual 11).

8. Industrial Land (% of subwatershed)

The fraction of a subwatershed devoted to industrial land can be an indirect indicator of the potential risk of illicit discharges and density of storm water hotspots that may warrant further investigation. In general, the greater the percentage of industrial land, the higher the risk for storm water pollution, illicit discharges, and other water quality problems. Subwatersheds with a lot of industrial land have greater restoration potential, since many of industrial operations are already regulated, which makes implementation of storm water retrofit, discharge prevention and source control practices easier. The industrial land metric can be easily derived from GIS land use layers.

9. Hotspot Density (Potential hotspots/square mile)

This metric measures the number of commercial, industrial, institutional, municipal and transport-related operations in the subwatershed with the potential to be storm water hotspots. Subwatersheds with a greater hotspot density are expected to generate higher storm water pollution loads, and are targets for pollution source controls, discharge prevention and on-site retrofit practices. Potential hotspots are located by analyzing business databases that classify subwatershed business operations by their Standard Industrial Code (SIC). Certain SIC classifications are strongly associated with hotspot potential, which are listed in Appendix A of Manual 8 *Pollution Source Control Practices*. Communities that are regulated under the EPA NPDES municipal storm water permit program may already have geospatial data on hotspot locations.

10. Condition of Sewer System (Average age in decades)

The average age of the sewer system can reveal clues about the potential risk of illicit discharges, sanitary sewer overflows and other sewage discharges to the stream network. In

general, subwatersheds with aging sewers have a greater risk of water quality problems, and may be good targets for discharge prevention practices and/or improved municipal operations. The average age of sewers is hard to define precisely since most are complex systems built (and upgraded) during different eras. If a community has detailed sewer infrastructure information on its GIS, it may be possible to extract sewer age from attribute tables. Alternatively, sewer age can be inferred from the age of subwatershed development, estimated by interviewing old timers in the local sewer authority, or examining maintenance records to look for clusters of sewage spill or overflow problems.

11. Sum of Forest, Parks and Wetlands (% of subwatershed)

This metric evaluates the aggregate land area in a subwatershed devoted to natural area remnants. Operationally, the metric is defined as the sum of subwatershed area in forest, wetland and park cover and is usually quite easy to calculate when these GIS layers are available. Subwatersheds that possess extensive natural area remnants normally have greater restoration potential, since they often enhance stream quality and offer possible sites for further natural area restoration, reforestation and wetland enhancements.

12. Citizen Concern (Index of concern)

Citizen concern is an important metric, as the public often expresses variable levels of subwatershed concern that ultimately affects the degree of stewardship and support for restoration efforts. The degree of citizen concern in each subwatershed can be hard to measure, but may be gleaned based on patterns of past stakeholder interest, volunteer activity, complaints or hotline reports. In other cases, citizen concern can be qualitatively measured simply by asking stakeholders.

13. Community Organization (Presence/absence)

Another non-technical metric is whether a watershed, neighborhood, civic, community or recreational group is active in the subwatershed. If such groups are active, they often strongly increase restoration potential since they can directly participate in restoration and stewardship activities. Determining the degree of community organization is usually subjective and is best made by talking with stakeholders that understand the community.

Review of Stream Corridor Metrics

14. Subwatershed Stream Density (Stream miles/square mile)

This metric indicates how much of the urban stream network in a subwatershed has been enclosed or eliminated in the past. High stream density generally indicates greater restoration potential since it suggests that more potentially suitable reaches are available to locate stream repair, reforestation and retrofit practices. Stream density is relatively easy to derive by adding the cumulative perennial stream mileage shown on GIS hydrology layers and dividing it by the total subwatershed area. Stream density is normally compared to a maximum regional reference value, which is obtained from an undeveloped subwatershed with an unaltered stream network.

15. Stream Corridor Forest Cover (% of corridor with forest cover)

This metric is an index of the potential area available for riparian reforestation or floodplain wetland restoration. Subwatersheds with high corridor forest cover are normally expected to have better stream quality. Paradoxically, subwatersheds with a low corridor forest cover usually have greater restoration potential, since they offer more opportunities for reforestation, better stream access, and require less clearing of existing mature forests during the construction of

restoration practices. The stream corridor can be operationally defined as a zone extending 100 feet in either direction from the centerline of perennial streams in a subwatershed. The resulting shapefile is then analyzed to compute the cumulative area of forest cover or canopy cover within the corridor zone. If forest cover is not currently available from the GIS, it can be digitized or visually estimated from recent aerial photos. Note: Since this metric is similar to metric 16, the team should choose one or the other, but not both.

16. Available Area in the Stream Corridor (Open acres/stream mile)

This metric is the reciprocal of stream corridor forest cover, and measures how much open land is available within the defined stream corridor. It is expressed as the total acres of open corridor per stream mile. In general, subwatersheds that have more open area available within the stream corridor have a greater restoration potential since they offer a greater range of potential sites for storage retrofits, stream repair and riparian reforestation practices. "Open" areas are determined by evaluating land cover within the stream corridor zone (e.g., 100 feet on either side of perennial streams), and is defined either as white space (no structures) or as grass cover, depending on what GIS layers are available. A maximum open acreage of 25 acres per stream mile is possible using the 100 feet on each side of the stream. Given that this metric is similar to the preceding metric (No. 15), the team should choose one or the other, but not both.

17. Road Crossings (Crossings/stream mile)

This metric is an index of the amount of stream interruption within a subwatershed and reveals clues about potential retrofit and stream repair opportunities. Road crossings are also an indirect measure of potential fish barriers that may preclude fishery recovery, although fish barriers are explicitly considered using another metric (No. 20). Headwater

crossings are a preferred measure of potential sites for storage retrofit and stream repair practices, and are defined as any crossings of a first or second order stream. The crossing metric is easily determined by superimposing GIS stream and road layers or by visually counting crossings shown on aerial photographs.

18. Density of Storm Water Outfalls (Mapped outfalls/stream mile)

The density of mapped storm water outfalls within a subwatershed reveals important information about storm water impacts, illicit discharge risks and threats to infrastructure. In addition, outfall density is a useful subwatershed indicator of overall retrofit feasibility since every outfall represents a possible storage retrofit site. Most communities regulated under the municipal NPDES storm water permit are required to maintain a GIS or paper map of their storm drain system. Outfall density can be easily computed from these maps as the total number of points where perennial streams and storm drains intersect in a subwatershed.

19. Rapid Baseline Assessment (RBA) Composite Scores (Various units)

Various metrics can be derived from physical, water quality or biological indicator sampling conducted during a rapid baseline assessment (RBA-- see Section 2.2). Most of the rapid assessment methods compute an overall or average score that represent conditions within the subwatershed (e.g., excellent, good, fair, poor). RBA should always be used in a CSA, although it can sometimes be hard to interpret in the context of restoration (e.g., does a “poor” score suggest that restoration is achievable, or desirable or hopeless?). It is usually a good idea to evaluate RBA data in the context of indicator predictions for the four urban stream classifications of the ICM model (See Manual 1, Appendix A). Subwatersheds that possess “outlier” indicator scores merit special attention (e.g., indicator scores are poor

when they are expected to be good, or are good when they are expected to be poor).

20. Connection to Downstream Waters (Open, impeded or unknown)

This metric assesses all major crossings located between a subwatershed and its downstream receiving water (e.g., river, lake or estuary) to determine whether aquatic life can freely move back and forth. Subwatersheds that are open to migration and/or re-colonization are assumed to have greater potential to restore fisheries and aquatic diversity, compared to subwatersheds where movement is partially or fully impeded. The connection metric is scored as open, impeded, or unknown, based on a visual inspection of crossings, dams and other barriers observed on maps or aerial photographs.

21. Stream Corridor in Public Ownership (% of corridor)

It is much easier to install restoration practices on publicly controlled land in the stream corridor, such as parks, greenways and floodplains, compared to private land. Consequently, subwatersheds that have a high percentage of public corridor ownership are normally thought to have greater restoration potential. The metric is computed by analyzing parcel ownership data within the defined stream corridor zone (e.g., 100 feet on either side of perennial streams).

22. Violations of Water Quality Standards (Violations/year)

If a community has historically sampled water quality at the subwatershed level, the resulting data can be transformed into summary metrics that examine the relative frequency with which water quality standards are violated (e.g., bacteria, dissolved oxygen, turbidity, and nutrients). Water quality metrics are often computed during the Existing Data Analysis (EDA—Section 1.2) or by evaluating the State 303(d) list. Subwatersheds that experience

frequent violations have a greater need for practices that can reduce pollutants to meet water quality standards, such as storm water retrofit, discharge prevention and pollution source control practices. This metric is similar in some respects to Metric 25, so the team should choose one or the other, but not both.

23. Fisheries Data (Various units)

Some communities may possess data on current or historical fish populations, barriers or habitat quality. If subwatershed-specific fishery data is discovered during the Existing Data Analysis, it should always be incorporated into the CSA. In most cases, subwatersheds that rank as having good or fair fish populations have better prospects for restoration than subwatersheds that are designated as poor.

24. Stream Corridor Recreational Value (Index)

Stream corridors differ greatly in their recreational use and public access. In general, subwatersheds where stream corridors are utilized for trails, bike paths, greenways or parks tend to attract greater public support for restoration and enhancement. By contrast, corridors that are privately owned or have poor or restricted public access tend to get much less attention. Generally, high recreational use indicates greater potential support for restoration, although some intense recreational uses may actually preclude use of parts of the corridor for reforestation, retrofit and stream repair practices. The recreational value of the subwatershed stream corridor can be subjectively determined and expressed in terms of a comparative index.

25. Water Quality Regulatory Status (Index)

The receiving waters of a subwatershed may be designated for special protection, have a unique water resource management use, or be subject to mandatory pollutant reductions if water quality standards are not being met (e.g.,

a Total Maximum Daily Load or TMDL). Each community has a different combination of natural resource, water use and water quality designations. The core team should first check to see if the water body is listed on the State 303(d) list for non-attainment (this may have already been done in the Needs and Capabilities Assessment- Section 1.1). A metric should be developed if significant differences exist in the regulatory status of subwatersheds (or the receiving waters they discharge to). The regulatory metric is usually expressed as a relative index number. This metric is similar in some respects to Metric 22, so the team should choose one or the other, but not both.

26. Severity of Flooding Problems (Index)

Flooding problems are often a major restoration driver in a CSA. The severity of flooding problems among subwatersheds can be measured in a number of ways, including the number of past drainage complaints, past FEMA modeling of flood risks, number of structures within the 100-year floodplain, and damage claims to private property and/or public infrastructure. In general, the more severe the flooding problems, the greater the restoration potential, which usually means that storage retrofits and improved riparian management practices are needed to solve the problem.

27. Severity of Streambank Erosion (Index)

The comparative severity of streambank erosion problems is seldom known until USA or other stream surveys are conducted in subsequent steps of the planning process. However, if a community has conducted geomorphic assessments or tracked drainage/erosion complaints in the past, they may wish to convert this data into a streambank erosion severity metric. In general, the more severe the erosion problems, the greater the restoration potential, which usually means that bank stabilization and storage retrofits are needed to address the problems.